Automatic Line Insulation Test Equipment for Local Crossbar Systems

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Moisture entering faults in the insulation of subscriber lines provides so-called "leakage" paths which reduce the insulation resistance. Testing the insulation resistance of all lines under the environmental conditions which tend to produce these leakages is a maintenance technique, relatively new, for detecting the insulation defects. The faults can then be corrected before they become serious enough to affect the customers' service. Subscriber reports are thereby reduced and the correction of the faults on a preventive maintenance basis tends toward a more uniform work load for the repair personnel. Rapid testing of the lines is necessary, otherwise the environmental conditions may change and the leakages will disappear without detection.

Rapid line insulation testing is practiced quite generally in all the switching systems throughout the Bell System, but the testing arrangements used are wholly or partially manually controlled in the testing and recording operations. While the benefits derived from rapid line insulation testing apply to all systems alike, this article is confined to a discussion of the entirely automatic testing and recording arrangements which are now being introduced in the No. 1 and No. 5 crossbar systems.

INTRODUCTION

The insulation resistance of subscriber lines is an important consideration in the design and operation of central office switching circuits. If the insulation resistance between the two conductors of the line, or the insulation resistance from the "ring" or "battery side" to ground, becomes low enough, the "leakage" current flowing produces the same effect as lifting the handset and failing to dial or to pass a number to the operator. This condition is called a permanent signal and the line is said to be "permanent." As long as the condition persists, the line is out of service both to incoming and outgoing traffic. Insulation resistance of a slightly

higher value will not cause a permanent signal, but its presence may interfere with other circuit functions, for example, dial pulses are distorted and a wrong number may be reached, the ringing signal may be tripped before the called party answers, or the switching circuits may fail to restore on hang-up of the receiver. If the insulation resistance is at least as high as the design limit, failures of the kind described above will not occur. The design limit for some switching systems used in the Bell System is 10,000 ohms; for others 15,000 ohms.

WHERE LINE LEAKAGES OCCUR

The outside plant distribution system for exchange lines usually consists of some underground cable, many miles of aerial cable to distribute the line conductors throughout the area and a small amount of open wire on the fringes. The insulation resistance of the cable conductors is normally quite high. If, however, a break in the cable sheath occurs moisture may enter and be absorbed by the paper insulation of the conductors near the break. This reduces the insulation resistance of the affected cable pairs. Sheath breaks may exist for a considerable length of time without reducing the insulation resistance sufficiently to cause any reaction on customer service. Eventually these sheath breaks will, if not detected and repaired, permit the entrance of sufficient water during a rain to reduce the insulation resistance to the point where permanent signals occur on several pairs. Then repairs must be made on an emergency basis to guard against a complete failure of all line circuits in the cable. One of the common causes of sheath breaks in some residential areas is gnawing by squirrels — squirrel bites.

Cable terminals are located on the poles or on the cable for making drop wire connections to the customers' premises. Binding posts mounted in a face plate within the terminal are connected to some of the cable pairs through a terminal cable stub joined to the aerial cable. Each cable pair is thus connected to binding posts in about four or five terminals on the average. When water or condensation wets the face plate, leakage currents will flow between the binding posts. If dirt and dust have accumulated on the face plates, the combined resistance of all leakage paths in parallel across the pair or to ground may become relatively low.

While open wire makes up only a small part of the outside plant circuits most areas have some lines containing from a few spans up to several miles of open-wire conductors. It is difficult to keep the open-wire plant in a condition so that it will be free from leakages under wet

weather conditions. Trees grow up into the wires and during rainy weather the branches often drop across the wires. When this occurs at many points on the open-wire run the combined leakage along the pair may become very low. In some localities, moss growing on the wires, salt spray or heavy fog conditions causing leakage at insulators are additional causes of low insulation resistance on open-wire lines.

Drop wire used to make the connection from the cable terminal to the customer's premises is subject to damage by abrasion and the insulation deteriorates from the effects of the weather. The old style of drop wire, a large amount of which is still in use in the plant, is insulated with a rubber compound and covered with a water proof cotton braid. When this braid protection is lost due to abrasion or effects of the weather after many years in service cracks form in the rubber insulation. Moisture enters these cracks in wet weather causing low resistance leakages. It is expected that the latest type of drop wire with the tougher neoprene covering will withstand the hazards for a longer period of time than does the old drop wire but undoubtedly the end of its useful life will ultimately be determinable by measurement of the insulation resistance under wet weather conditions.

Inside wiring on the customer's premises often remains in service for a long period of time and the insulation deteriorates over the years. If the insulation is in poor condition, inside wiring will develop leakages during periods of prolonged high humidity indoors which occur frequently during the summer months.

EFFECTS OF WEATHER ON LINE INSULATION RESISTANCE

When weather conditions are favorable — clear weather with low humidity — the insulation resistance of the line conductors in the outside plant is quite high compared to the design limit for central office switching circuits. When the plant becomes thoroughly wet from a hard rain the insulation resistance drops very considerably because of leakages which are in parallel all along the line. Fig. 1 shows this very clearly. The data for the curves in this figure were collected in a special study conducted in 1931 to determine the insulation resistance distribution of exchange lines in underground and aerial cable and open-wire plant under different weather conditions — dry, humid and wet. About 6,000 dial lines selected at random in twelve large cities in different parts of the United States were tested under different weather conditions and no repairs were made throughout the study period except to correct unsatisfactory service conditions. The tests were made with the voltmeter

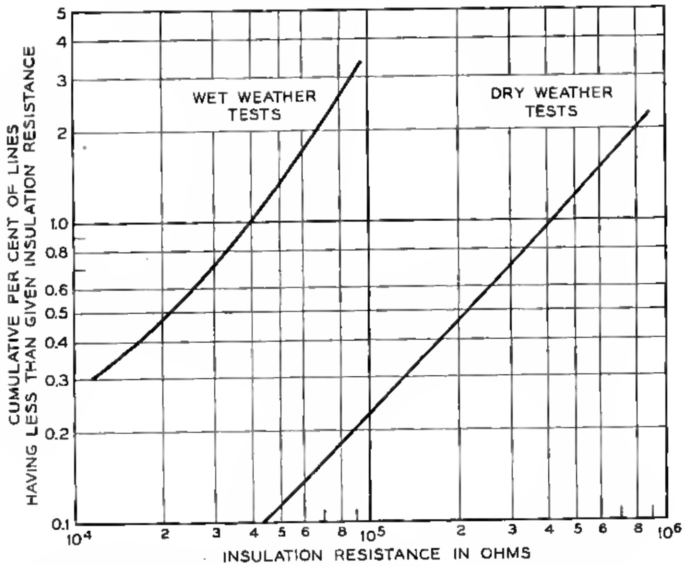

Fig. 1 — Wet weather versus dry weather tests — all types of Outside Plant combined.

test circuit of the local test desk which is used for testing subscriber lines reported in trouble. The speed at which lines can be tested from the test desk is necessarily slow because each number must be dialed or called individually therefore, only a small sample of lines was selected from any one office. Rapid line insulation test equipment was not in use in any area when this study was made.

The upper curve of Fig. 1 shows that about 0.3 per cent of the lines were below 11,000 ohms in wet weather while in dry weather only about 0.3 per cent of these same lines were below 140,000 ohms. Similarly, in wet weather two and one-quarter per cent of the lines were below 47,000 ohms but in dry weather only two and one-quarter per cent were below 900,000 ohms. The same wet weather test data summarized by types of outside plant is shown in the curves of Fig. 2. Lines in underground cable only, show the highest line insulation resistance. Those with aerial cable are next and those with some open wire have the lowest insulation resistance.

Fig. 3 shows the wet weather line insulation resistance distribution of 11,600 lines in an eastern city where the exchange outside plant had been thoroughly reconditioned prior to conversion from manual to crossbar dial operation in 1940. The upper curve represents the approximate distribution before reconditioning and the lower curve represents the

distribution after the reconditioning was completed. The lower curve can be considered as representative of an outside plant in good condition as of the year 1940 when rapid line insulation testing was not yet used. Since that time, a considerable number of improvements leading to better insulation resistance characteristics have been made in outside plant items, such as drop wire and cable terminals, and a higher average insulation resistance would currently obtain. However, during wet weather, an undesirably large number of lines would still be closer than desired to the design limit.

MAINTENANCE WITHOUT RAPID LINE INSULATION TESTING

It may appear at first sight that the per cent of lines near or below the design limit is so small as to be unworthy of particular notice. However, an examination of this from a maintenance standpoint will prove otherwise. The testing of lines reported in trouble and dispatching of craftsmen on the outside to make repairs are handled from a local test center which on the average serves about 50,000 stations. There will be about six local test desk positions manned to do the testing and dis-

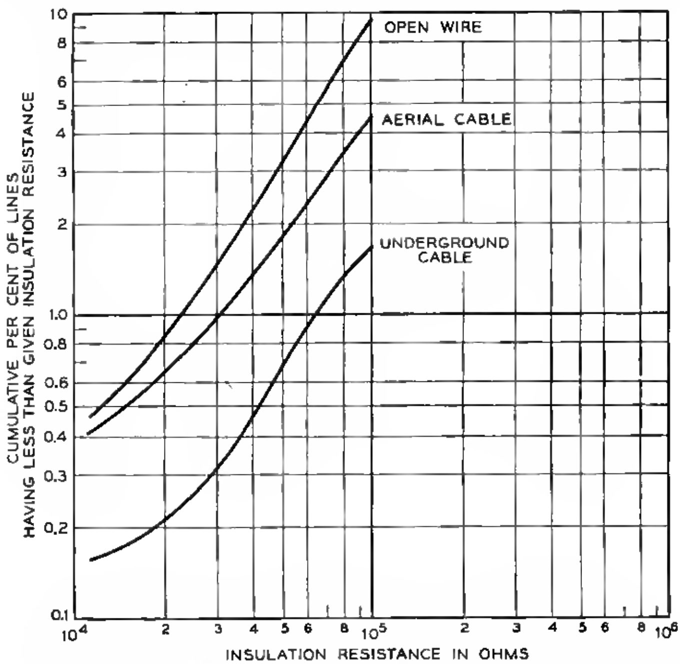

Fig. 2 — Wet weather tests — insulation resistance by types of Outside Plant.

patching work. Such a test center would handle at the current trouble rate about 120 reports on subscriber lines per day. If the outside plant is in a condition represented by the lower curve of Fig. 3 where 0.2 per cent of the lines are below 10,000 ohm resistance, tbis represents 100 additional stations in the region where service reactions may be expected from wet weather conditions. Consequently where these plant conditions obtain, there is usually a noticeable increase in subscriber's reports in wet weather and the repair load rises sharply. Without line insulation test equipment to test the lines rapidly while the low insulation resistance obtains, there is no way to pick out the worst lines from an insulation resistance standpoint after the weather has cleared. Visual inspections are costly and superficial indications do not always give reliable evidence of low insulation resistance. Consequently the large percentage of repairs to correct insulation defects are made as a result of subscriber reports and only a small per cent by routine preventive maintenance where rapid line-insulation testing equipment is not used.

MAINTENANCE WITH RAPID LINE INSULATION TESTING

The only experience to date witb the fully automatic line insulation test equipment for crossbar offices is in the Media, Pa., No. 5 crossbar office. This test equipment has been in use for about one year and low insulation resistance cases recorded on each test have been investigated and repairs made. The condition of the outside plant in the exchange area is represented in Fig. 4. The curves in this figure are based upon the results of tests of the 4200 working lines in the summer of 1952 under very wet conditions of the outside plant.

The small percentage of lines below 40,000 ohms indicates that the poor insulation cases are being corrected well before reaching the stage where the customers' service would be affected. This is done with a minimum of maintenance effort as the test equipment spots the line automatically.

DETECTING SHEATH BREAKS

While sheath breaks in aerial cable are brought to light by rainy weather it is inadvisable to wait for rain to disclose them because of the possible serious effects on service and the need then for repairs on an emergency basis. Rapid line-insulation testing techniques have been very successful in disclosing sheath breaks in aerial cable. During the night the cable sheath cools and as the pressure inside decreases, outside air with a high moisture content enters the sheath break. The paper

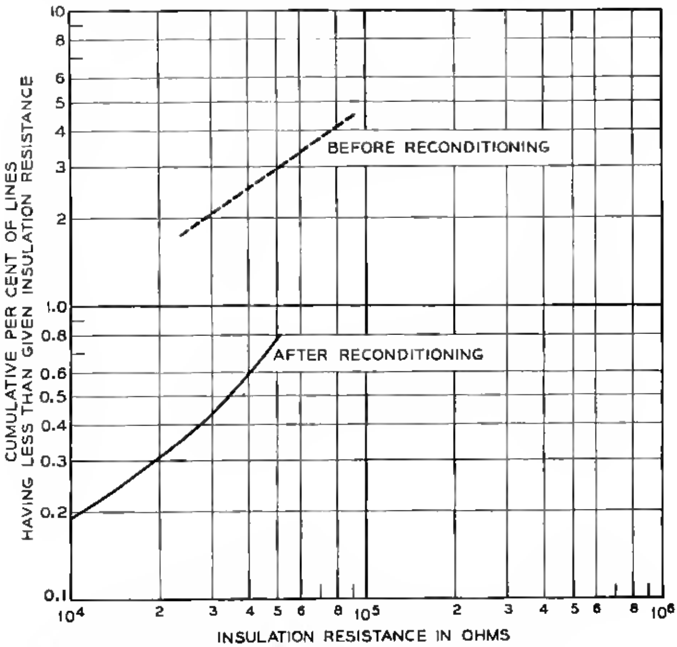

Fig. 3 — Wet weather tests — reconditioned Outside Plant.

insulation of one or more pairs near the hreak ahsorhs the moisture and the insulation resistance of the affected pairs is lowered. Tests made from ahout 3 A.M. to 5 A.M. are effective in detecting these leaks and by applying the latest fault locating methods, many of the sheath breaks can he located. The test equipment is so arranged that, for the most part, lower leak conditions on the line which may he present outside of the aerial cahle will not register on these tests for cahle defects.

BENEFITS DERIVED FROM RAPID LINE-INSULATION TESTING

With the aid of rapid line-insulation test equipment the maintenance personnel can correct the greater part of insulation defects on a preventive maintenance hasis which results in a reduction of suhscriber reports. Service to the customer is therehy improved, maintenance effort is reduced and repairs on an emergency basis often involving the expenditure of overtime are required less frequently. Rapid line-insulation testing is also of great value in rapidly determining the extent of storm or flood damage and makes it possihle to direct immediate efforts where the greatest henefits will he derived.

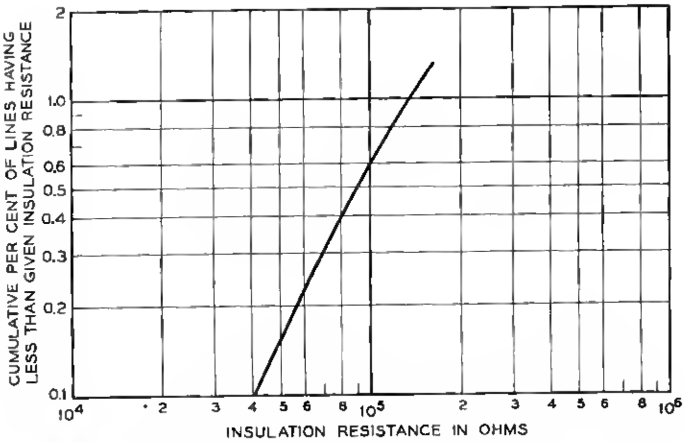

Fig. 4 — Wet weather tests — automatic line insulation testing equipment used.

CROSSBAR TEST EQUIPMENT — TYPES OF TESTS AND SENSITIVITIES

The crossbar line-insulation test equipment is arranged to make three different kinds of tests from the standpoint of the way in which the resistance measuring circuit (line-insulation test circuit) is connected to the line and to battery or ground. Each kind of test may be made in three different resistance ranges, hence there are nine different tests. When the test equipment is performing one of these tests a record is made of all lines which have an insulation resistance below the top limit of the particular test. Each test range is divided into three bands of resistance and the record indicates whether the insulation resistance lies within the first quarter (low band), the second quarter (medium band) or the upper half (high band) so that preference can be given to the worst cases in clearing the trouble. The test numbers, ranges and resistance bands are shown in the Table I.

SHORT AND RING GROUND TEST

The first kind of test is called "short and ring ground test." This test measures the leak in the way in which it affects the line circuits, pulsing circuits and supervisory circuits of the central office switching system. The line-insulation test circuit (LIT circuit) which is described later on is connected to central office battery potential and to the line in the manner shown in Fig. 5 (a). As indicated in this illustration, leakage resistance from ring to tip and from ring to ground are measured

TABLE I — CROSSBAR LINE-INSULATION TESTS

Types of Tests and Test Numbers			Range	Resistance Bands* (kilo-ohms)		
Short and Ring Ground	Tip and Ring Ground	Foreign E.M.F.		Low	Medium	High
1	4	Not used	A	0–40	40–80	80–160
2	5	7	B	0–160	160–320	320–640
3	6	8	C	0–640	640–1250	1250–2500
Not used	Not used	9	D	0–1250	1250–2500	2500–5000

* The equipment is arranged so that by cross connection changes the bands of resistances in each range may be halved or doubled, if necessary, to meet local conditions.

in parallel. If the line-insulation resistance is more than the top limit of the test range, the test equipment proceeds to the next line. If, however, the resistance measured is less than the top limit the test equipment immediately retests the line with the central office ground removed as shown in Fig. 5 (b). This re-test measures the leakage from ring to tip. If leakage from ring to tip only is indicated the drop wire is probably the cause.

The No. 1 test is run under wet weather conditions to detect all lines which are below the top limit of this test (normally 160,000 ohms). If the maintenance force keeps these cases cleared out by running tests during every rain the wire plant can be kept in good condition. During long periods of dry weather all line insulation test indications previously recorded may have been investigated, then if a light rain occurs it may be desirable to run the No. 2 test to provide a satisfactory number of failure indications for subsequent investigation. The No. 2 test can also be used to detect leakages in inside wiring which occur frequently during the summer when houses are unheated and the inside humidity

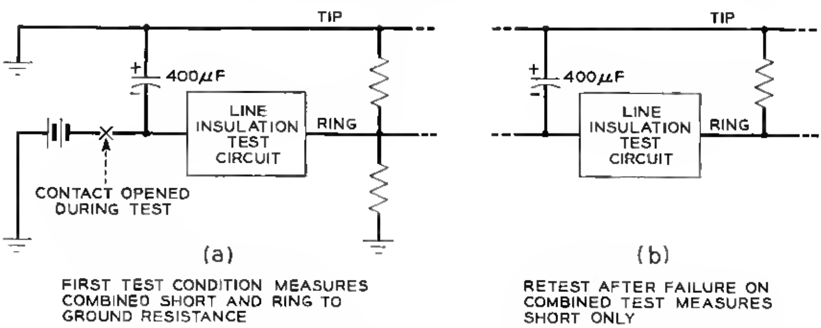

Fig. 5 — Short and ring ground test.

is very high. Tests to disclose insulation defects in inside wiring are made when the weather is clear with low outside humidity at which time leakages in other parts of the exchange plant will rarely be found.

TIP AND RING GROUND TEST

The "tip and ring ground" test can be made in three ranges of sensitivity as shown in Table I. The arrangement of the test circuit for this type of test is shown in Figure 6. The first test condition, Fig. 6 (a), measures the combined leakage resistance from tip and ring to ground. The tip and ring are connected together therefore leakage across the pair is not indicated. This eliminates practically all of the drop wire

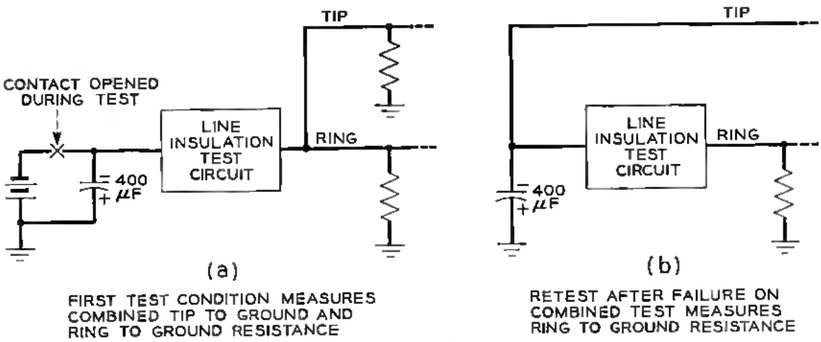

Fig. 6 — Tip and ring ground test.

leakages. If a failure is indicated on the first test condition, a re-test is made under the condition shown in Fig. 6 (b) to check only the resistance from ring to ground. If the ring tests clear it is known that the leakage is from tip to ground. This kind of test is of particular value in checking terminal face plate leakages which are predominately leakages from tip to ground. This type of test can also be used to check that tip conductors on party lines in message rate areas are free of low resistance grounds which might result in wrong party identification on calls made by the ring party.

FEMF TEST

The FEMF (foreign e.m.f.) test is used to measure leakages in cable to detect sheath breaks. These leakages are high resistance compared to other leaks which may be present across the pair connected for test or from the pair to ground. To make the latter ineffective so as not to

mask the higher resistance cable leakages the test circuit is grounded and connected to the line with the tip and ring short circuited as shown in Fig. 7. The test circuit measures the leakage current flowing from the pair connected for test to the ring conduetors of other subscriber lines which are connected to battery potential in the central office. Leakages outside the cable will not cause leakage currents to flow through the line insulation test circuit. This test is called FEMF because it measures leak in the same way as does the test desk voltmeter when the FEMF test key is operated to connect ground instead of test battery to the voltmeter. Leakages as high as about 2 megohms can be successfully located after the cable has been identified by analysis of pairs affeeted by leaks.

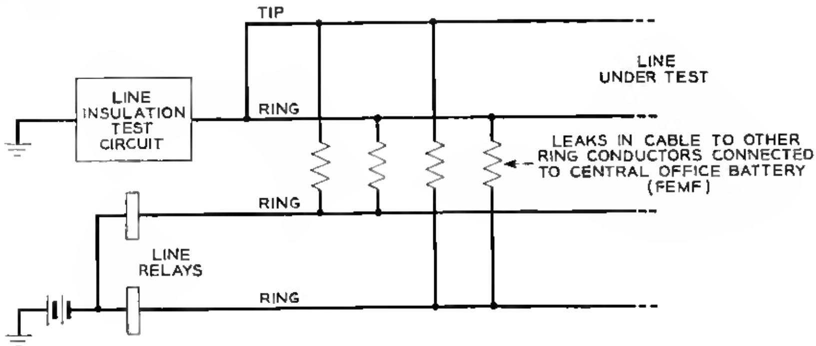

Fig. 7 — Foreign E.M.F. test.

TEST AND RECORDING CIRCUITS

The equipment for automatically measuring and recording line-insulation resistance consists of three principal parts. First, the device for measuring the low currents involved; second, the means for connecting this measuring device to each of the lines in rapid succession; and third, the apparatus required for recording the faults discovered.

The first of these, known as the line-insulation test circuit, is capable of detecting insulation resistance as high as ten megohms, with fast enough response, so that a satisfactory rate of line testing (about 10,000 to 12,000 lines per hour) is attainable. It is provided with a filter to attenuate both 25- and 60-cycle interference, so that leakage faults may be separated from other types such as induction from power lines. As shown in Table I, its sensitivity may be easily changed, so as to be compatible with atmospheric conditions, the kind of test to be made, and the condition of the outside plant. When a particular sensitivity or

"range" is chosen, the insulation fault detector will report all lines having lower insulation resistance than the chosen value, and as already stated it will further identify those lines having insulation resistance lower than one-half and one-quarter of this resistance.

This test circuit is connected to each of the lines in rapid succession by the line-insulation test control circuit. As shown in the block diagram of Fig. 8, the control circuit appropriates the control and testing wires between one of the markers (usually marker No. 2) and each of the line link frames. The arrangement shown is for a No. 5 crossbar office, but the No. 1 crossbar arrangement is similar in principle. By means of these appropriated connections the control circuit is able to select the

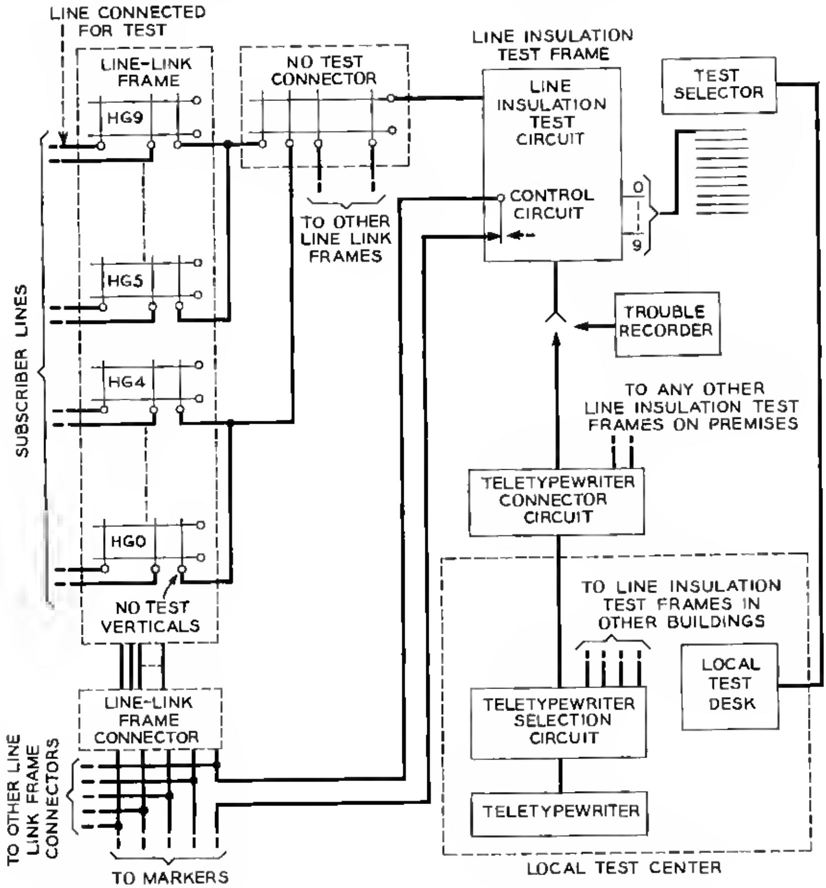

Fig. 8 — Block diagram of line insulation test control circuit connections.

lines and if the selected line is not busy its tip and ring conductors are connected to the insulation resistance measuring circuit (line-insulation test circuit). To establish this connection, the control circuit chooses an idle line link to connect the line vertieal to the no test vertical and the test path is completed through the no test connector to the line-insulation test frame.

The operation of the control circuit may be started in the central office by operation of keys at the test frame, but it is more commonly started by remote control from the local test center. This permits insulation tests to be made even though the central office is unattended. When the control circuit is started, it must also be directed to make one of the three types of tests, and to choose one of the three test sensitivities for each of these types as shown in Table I. This is accomplished by operating one of nine keys at the test frame or by selecting the test trunk at the test center and dialing one of nine codes and then operating a key at the test desk. Either action chooses the type of test and the sensitivity, and causes the test circuit to start. A tenth key or a tenth code is used to stop the test before the end of a complete cycle, when this is required, so that the type of test or the sensitivity may be changed.

A pre-arranged regular pattern is followed in testing the lines. A line link frame is selected, a particular five lines are tested, and then the frame is released, and the next frame is selected, and another five lines are tested, and so on. Lines found busy, dial PBX trunks and line link frame terminations of intertoll trunks and similar circuits which would cause false operation of the test circuit are passed by without test. The line link frames are selected in order, beginning with the lowest numbered frames and continuing to the highest. When one cycle through the frames has been completed, another cycle will be started. However, on the next cycle, different groups of five lines will be tested. On the first cycle, the five lines in vertical group 0, horizontal group 0 will be tested, on the second cycle, the five lines of vertical group 1, horizontal group 0 will be tested, in each line link frame and so on until all lines in horizontal group 0 of all line link frames have been tested. On subsequent cycles the lines of other horizontal groups are tested in regular order.

Testing only five lines for each selection of a line link frame minimizes interference with traffic. Since one to two seconds is required for testing five lines, there will be only a slight delay to calls which require access to the frame. In addition, a heavy traffic load will cause the control circuit to stop insulation testing and restore to service the marker whose cabling it has been using. When the traffic has been reduced sufficiently, the test will be restarted automatically.

When a line fault is discovered, the control circuit makes use of either of two types of mechanism to record (a) the location of the line on the line link switches, (b) the type of test being made, and (c) a rough approximation of the insulation resistance. Since a substantial time is required to make this record, the line link frame is restored to service during this interval, to reduce interference with service. One of the above two devices is the trouble recorder, used only in the No. 5 crossbar offices. The control circuit connects itself to this machine in much the same way that a marker does, when it needs to record a trouble. Having made this connection, a card is perforated showing the line location and other data pertinent to the trouble indicated. The other device consists of teletypewriter equipment at the central office which transmits the required data to a teletypewriter page printer located at the local test center. The equipment at several central offices has common use of the same page printer at the test center and several test circuits in one building use the same teletypewriter transmitting equipment. This second recording arrangement is the more convenient of the two, since it produces the record at the place from which the activities of the outside plant repair force are directed. This arrangement is available for both No. 1 and No. 5 crossbar offices. A typical teletype record is shown in Fig. 9.

LINE-INSULATION TEST CIRCUIT

The insulation resistance measuring device is required to respond, not only to the very low current (five micro-amperes) obtainable with insulation resistance up to ten megohms, but it must also give good discrimination between resistance values in the order of 20,000 ohms. This is accomplished by desensitizing the measuring device by means of series and shunt resistors when a test using less than the maximum range is desired. A second requirement is that the measuring device be low in resistance so that the time constant of this resistance in combination with the line and filter capacity will be low enough to attain high testing speeds.

These leakage current amplitudes are so small that amplification is required in order to actuate the recording and control mechanisms of the measuring system. These small direct currents could be amplified by means of a dc amplifier. However, since it is easier to design and construct an ac amplifier of suitable stability, it is desirable to use a measuring device which has an alternating voltage output which varies with the direct current input.

A type of magnetic modulator, called a magnettor, which has these

desirable characteristics, is used as the current measuring instrument. It has a low impedance input circuit, in which the low amplitude dc leakage current flows. An alternating current of constant amplitude and frequency is supplied to separate windings of the magnettor, so that, as explained below, its output circuit delivers an alternating voltage which varies with the dc input. Fig. 10 shows the basic circuit, which operates as follows. Two identical windings, a and a′, and two other identical windings, b and b′, are wound on identical permalloy cores. Windings

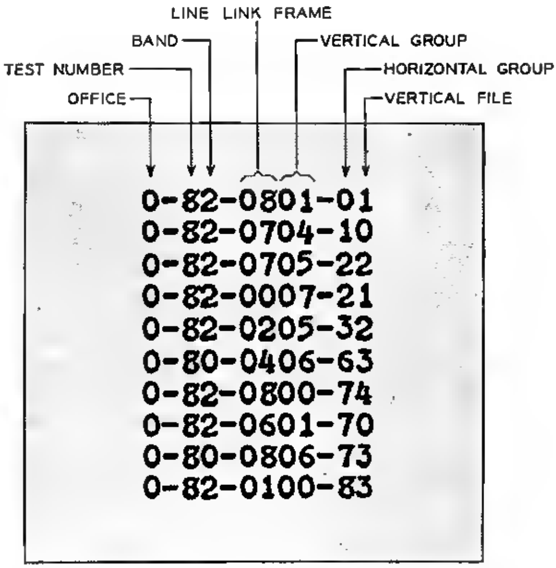

Fig. 9 — Teletype record of failures.

a and a′ are connected in series and supplied with an alternating current. The magnettor cores have a characteristic as shown in Fig. 11 (b), and the amplitude of the input voltage is great enough so that the core is driven to saturation on each half cycle. Fig. 11 (c) shows the resulting flat topped flux versus time curve*. Since the voltage induced in winding b is proportional to the rate of change of flux, it will have a wave form as shown in Fig. 11 (d). The voltage peaks occur when the flux rate of change is maximum, and during the "flat" intervals the induced voltage is small. Since the b and b′ windings are connected so that their output voltages are in opposition (see Fig. 11 (d)) the net output with no dc

* The wave shapes of Figs. 11 (c), 11 (d), 11 (e) and 11 (f) have been exaggerated to illustrate the action involved.

input will be zero. Manufacturing tolerances which produce dissimilarities in the windings and cores may cause a small output with zero dc input.

When the dc leakage current flows through windings b and b′, a bias flux is established in each of the cores. This causes the shape of the flux versus time curve to be changed as illustrated in Fig. 11 (e). Since the ac input will saturate the cores, both half cycles of the wave will be flat topped, but the flat portion of one-half cycle will be increased and the other decreased. Also the steeper parts of the curve will be brought closer together on one-half cycle and further apart on the other.

As illustrated in Fig. 11 (e) the dc bias will have a different effect upon the flux in each of the two cores. In one core the bias aids the positive half cycle of the input current, and in the other the negative half cycle. The result is that the core reaches saturation more quickly and, therefore the flux curve is flatter on the half cycle which is aided by the bias.

This change in the shapes of the flux time curves produces corresponding changes in the shapes of the voltage-time curves of the output windings b and b′. These are shown in Fig. 11 (f). The peaks of the voltage curves occur at the points of maximum rate of change of the flux curves, and of course the flat portions of the voltage curves (near zero) are lengthened or shortened depending upon the flatness of the flux curve tops. This skewing of the two voltage curves prevents the output voltage cancellation which was obtained with no dc, and gives

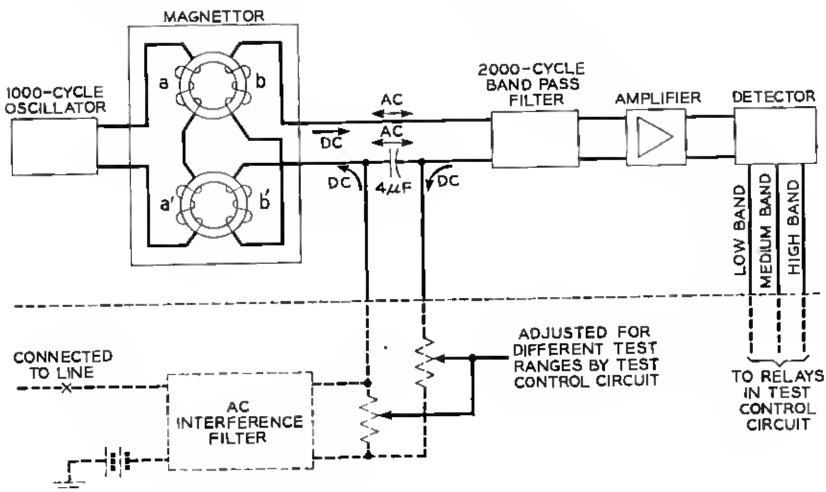

Fig. 10 — Block diagram of line insulation test circuit.

a resultant output which contains even harmonics of the input voltage. The second harmonic is selected by means of a filter for use as an indicator of the presence of leakage current.

The second harmonic is amplified by a three stage negative feedback vacuum tube amplifier, whose output is applied to the grids of three thyratrons. Adjustments are made, as described in the following, so that one of the thyratrons conducts when the insulation resistance is less than the value selected for the test, an additional thyratron conducts if the insulation resistance is one-half of this value or less, and all three conduct if the resistance is one-fourth or less of the selected value. Three relays, whose windings are connected in the anode circuits of the thyratrons, are actuated when the associated thyratrons conduct and cause a record of the trouble to be made, or cause the control circuit to select another line if the insulation resistance is above the range of interest.

In order to calibrate the detecting circuit, a test resistor of 160,000 ohms is connected to the magnettor by operation of a key. The amplifier gain is then adjusted so as to just cause conduction of the thyratron

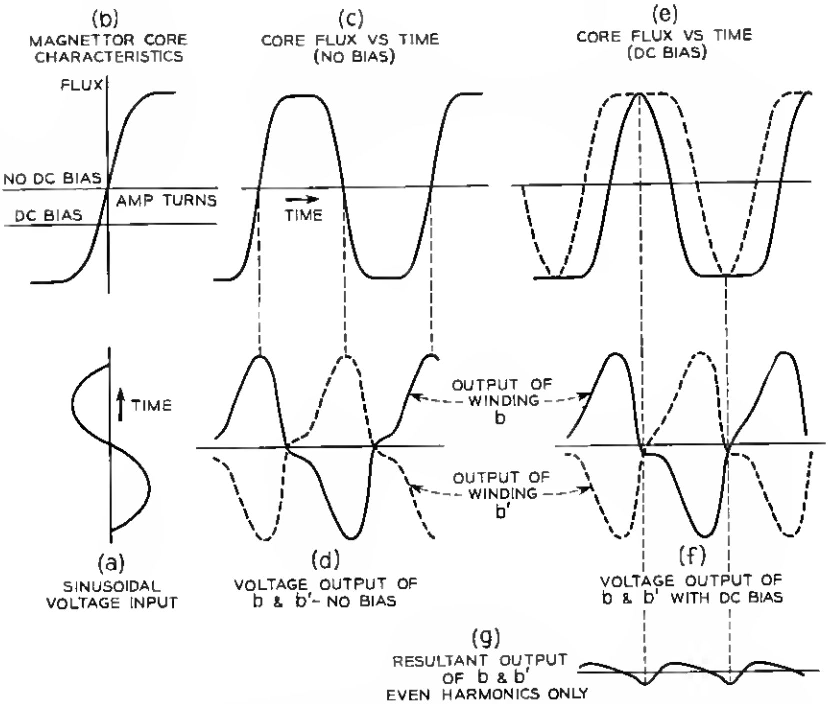

Fig. 11 — Graphical representation of voltage and flux in the magnettor.

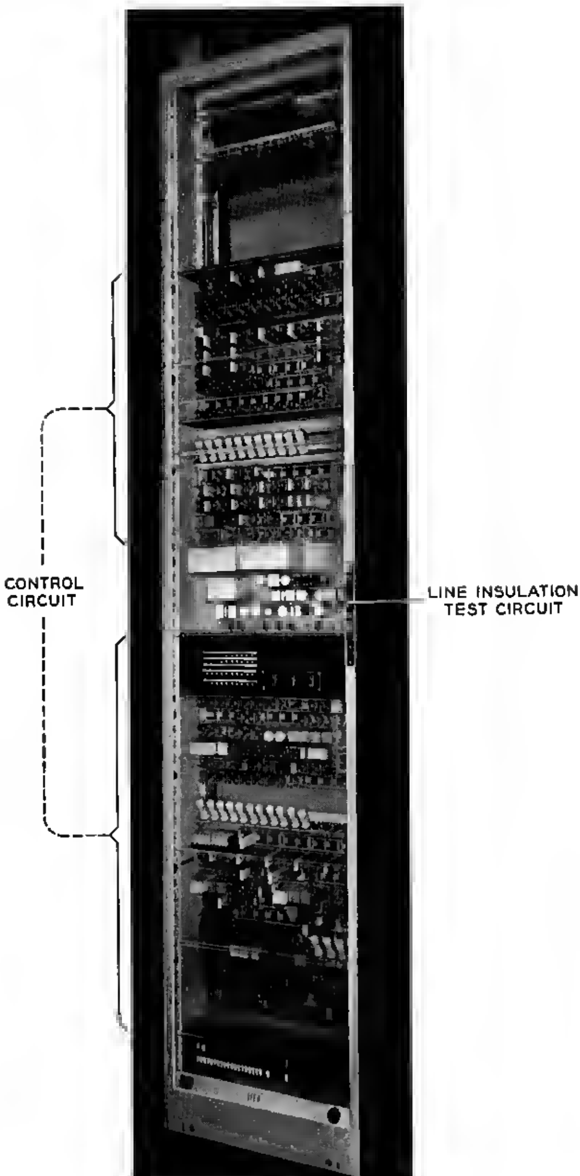

Fig. 12 — Front view of line insulation test frame.

which responds to the lowest insulation resistance value. Test resistors of 320,000 ohms and 640,000 ohms are then substituted and the grid hias of the other thyratrons adjusted so that they just conduct on the proper value of resistance. This procedure calibrates the device for one range, using a shunt and series resistor which corresponds to this range.

Facilities are provided for substituting suitable test resistors for checking the calibration of other ranges, with the shunt and series resistors for the range connected to the magnettor.

EQUIPMENT FEATURES

The apparatus components of the test control circuit and the line insulation test circuit are assemhled and wired in an 11-foot hay, 23 inches wide. Fig. 12 is a front view of the test frame. Fig. 13 is an enlarged view of the line insulation test circuit equipment and the control panel which includes features for checking the accuracy of the test circuit and for calibrating it. When the teletype method of recording failures

Fig. 13 — Front view of control and test panel (at bottom) and line insulation test unit (center) for No. 5 crossbar.

is used, the teletype transmitting equipment common to all line insulation test frames in a building is mounted in a separate 23-inch bay and occupies about one-third of the vertical space.

CONCLUSION

The initial installation of the automatic line insulation test equipment in a No. 5 crossbar office has been in operation for more than a year and the maintenance advantages of remote control of starting and automatic testing and recording have been fully demonstrated. It is expected that any future developments of line insulation test equipment undertaken for other switching systems will follow this same general pattern.

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